COMBINATIONS OF RESPONSE-DEPENDENT AND RESPONSE-INDEPENDENT SCHEDULE-CORRELATED STIMULUS PRESENTATION IN AN OBSERVING PROCEDURE

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Pigeons pecked a response key on a variable-interval (VI) schedule, in which responses produced food every 40 s, on average. These VI periods, or components, alternated in irregular fashion with extinction components in which food was unavailable. Pecks on a second (observing) key briefly produced exteroceptive stimuli (houselight flashes) correlated with the component schedule currently in effect. Across conditions within a phase, the dependency between observing and presentation of the stimuli was decreased systematically while the density of stimulus presentation was held constant. Across phases, the proportion of session time spent in the VI component was adjusted from 0.5 to 0.25, and then to 0.75. Results indicate that rate of observing decreased as the dependency between responses and stimulus presentations was decreased. Further, discriminative control by the schedule-correlated stimuli was systematically weakened as dependency was decreased. Increasing the proportion of session time spent in VI decreased the rate of observing. This effect was additive with the manipulation of the dependency between observing and presentation of the stimuli. Overall, these results show that conditioned reinforcers function similarly to unconditioned reinforcers with respect to response–consequence dependencies, and that stimulus control is enhanced under conditions in which the relevant stimuli are produced by an organism's behavior.

Key words: response-independent schedules, conditioned reinforcement, brief stimuli, observing, concurrent operants, discriminative stimulus, key peck, pigeon

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Although response-dependent outcomes are central to an understanding of operant behavior, researchers have long recognized that events occurring independent of responding may also have systematic effects on behavior (Imam & Lattal, 1988; Timberlake & Lucas, 1985; Lattal, 1974; Rachlin & Baum, 1972; Staddon & Simmelhag, 1971; Skinner, 1948). Investigations of such response-independent effects have focused almost exclusively on unconditioned stimuli such as food. Little is known about the effects of response-independent presentation of stimuli paired with food—discriminative and conditioned reinforcing stimuli. The present study was directed to this issue.

Of particular interest to the present line of research are studies that explore the combinative effects of response-dependent and response-independent schedules of stimulus presentation. Investigations of this sort involve fixed time (FT) or variable time (VT) schedules superimposed on underlying response-dependent schedules of reinforcement. (FT and VT schedules arrange reinforcer deliveries irrespective of behavior following fixed or variable time intervals, respectively.) Such arrangements involving some combination of response-dependent and response-independent schedules are typically referred to as conjoint schedules (Catania, Deegan, & Cook, 1966).

The most consistent effect of superimposing response-independent schedules on response-dependent schedules of reinforcement is a decrease in response rates (Burgess & Wearden, 1986). The arrangements that have produced the most consistent reduction in rate of behavior relative to response-dependent baseline performance are conjoint variable-interval variable-time (VI VT) schedules. Rachlin and Baum (1972, Experiment III-B) compromised the dependency between pecking and access to food by superimposing various VT schedules of food presentation on a VI 3-min schedule that was held constant across conditions. In comparison, Lattal (1974) held the density of food presentations

constant across conditions and varied the proportion of food deliveries that were dependent upon a response. Similar results were obtained in both experiments; as the number of response-independent reinforcer deliveries increased, the rate of food key pecking decreased.

Marr and Zeiler (1974) investigated the effects of response-dependent and response-independent brief-stimulus presentations on food-maintained key pecking of 2 pigeons. A fixed-interval (FI) 15-min schedule of food delivery was arranged throughout the experiment. In all conditions, food was delivered 0.5 s after the response that satisfied the schedule requirement. In experimental conditions, the brief stimulus (a 0.5-s key-color change) was produced according to FI 3-min, VI 3-min, FT 3-min and VT 3-min schedules, respectively. Each of these arrangements was examined under conditions in which the brief stimulus was paired with the food schedule, and under conditions in which the brief stimulus was never paired with food. With respect to the paired conditions, both FI and FT schedules of brief stimulus presentation produced positively accelerated patterns of responding similar to those typically produced by FI schedules of food reinforcement. In contrast, schedules of VI and VT brief stimulus presentation produced less poststimulus pausing. This difference is similar to the difference in response patterning obtained with VI schedules of food reinforcement compared to those obtained with FI schedules. Whereas the FI and VI schedules of brief-stimulus presentation enhanced rates of behavior early in the FI 15-min food interval, FT and VT brief-stimulus presentations reduced such responding. Early conditions in which the brief stimulus was unpaired with food had little effect on behavior, indicating that stimulus–food pairings were necessary to produce patterns of responding similar to those observed under schedules of food delivery. The authors concluded that response-independent delivery of food-paired brief stimuli had effects on response patterning comparable to those of unconditioned reinforcers under similar circumstances.

One might also ask whether response-independent delivery of conditioned stimuli has similar effects on behavior maintained by the presentation of conditioned stimuli. To address this question, Lieving, Reilly, and Lattal (2006) used an observing-response procedure in which key pecks produced food and treadle presses produced food-correlated stimuli. In Experiment 1, treadle presses during VI food components changed the food-key stimulus for 5 s to a color previously correlated with the availability of food. In the experimental condition, treadle presses were rendered ineffective, and VI-correlated stimuli were presented according to a VT schedule during VI food components. The VT schedule was yoked to each pigeons' own performance during baseline, such that the density of VI-correlated stimulus presentations was held constant across conditions. All pigeons showed a substantial decrease in rate of treadle pressing during this condition. When the baseline conditions (response-dependent stimulus presentations) were reinstated, responding recovered to levels similar to those observed during the original baseline.

The results of these experiments are similar to those obtained when similar manipulations are conducted on behavior maintained by unconditioned reinforcement. Thus, the limited available literature suggests that response-independent presentations of conditioned stimuli or food can produce similar effects on behavior. The present study was designed to investigate further the effects of response-independent delivery of schedule-correlated stimuli in the context of an observing procedure. The present study was also concerned with the discriminability of the background reinforcement context—a variable thought to modulate the reinforcing efficacy of conditioned stimuli (Dinsmoor, 1983; Fantino, 1977). Thus, the present study included manipulations of the proportion of session time spent in either VI or extinction (EXT) components of the mixed/multiple schedule operating on the food key. These manipulations were conducted to examine the possibility that the effects of response-independent delivery of schedule-correlated stimuli are modulated by the proportion of the session in which food reinforcers are available. For example, it is possible that a greater percentage of the session spent in VI components might decrease observing or decrease discriminative control by the schedule-correlated stimuli.

METHOD

Subjects

One female (250) and 5 male (96, 289, 457, 1770, 1774) adult White Carneau pigeons (*Columba livia*) served as subjects. All subjects were experimentally naïve and maintained at approximately 83% of their free-feeding body weights. The subjects were housed in individual cages in a colony room where they had free access to fortified water and grit. The colony was kept on a light/dark cycle with a light duration of 16.5 hours beginning at 7AM.

Apparatus

Sessions were conducted in a standard three-key operant chamber. The chamber was light- and sound-attenuating and located in a dark room. An exhaust fan in the chamber and a white noise speaker outside the chamber served to further mask outside noise. The experimental chamber measured 30.5 cm × 35 cm × 35 cm. Keys were arranged 23.5 cm from the floor of the chamber and were spaced 5.7 cm apart. Only the left and center keys were operable. A houselight provided general illumination in the chamber. A solenoid-operated food hopper was used to deliver 3-s access to mixed grain. Response keys required a force of 0.12 N to register a response. The left key was illuminated red, and the center key white for all subjects across all training and experimental conditions. All experimental events were controlled and data collected by a standard PC using MED-PC IV software and located in an adjacent room.

Initial Training

Experimental sessions were conducted 7 days per week at approximately the same time every day. Each session began with a 5-min blackout period, during which all lights in the experimental chamber were off and responses produced no scheduled consequences. The pigeons were first trained to eat from the food hopper and then trained with food to peck the white center key via the method of successive approximations. Once key pecking was established, all pigeons were exposed to 21 sessions in which pecking produced food according to a VI 40-s schedule of reinforcement. Before the introduction of the left (observing) key, all pigeons were exposed to training sessions in which the schedule of food reinforcement on the center key alternated between VI 40-s and EXT components (see below for a discussion of the stimuli accompanying each component). During initial training, the VI components terminated following food presentation. Duration of EXT components was determined by drawing from a 20-element equal probability distribution (Fleshler & Hoffman, 1962) of values identical to but independent of the values constituting the VI 40-s distribution. The sequence of VI and EXT components was randomly determined without replacement. Thus, the maximum number of times that a component could be repeated was once.

During training sessions and throughout the experiment, the houselight was programmed to flash at different rates in the VI and EXT components of the multiple schedule. Flashing the houselight on and off at a high rate (every 0.1 s) served as the S+ signaling the VI component and a lower flash rate (0.66 s) served as the S- signaling the EXT component. In the majority of prior studies on multiple schedules, stimuli were presented on a response key. However, pigeons may move away from the response key when S- is presented (Hearst & Franklin, 1977). Using the houselight made it unlikely that withdrawal from the response key would reduce contact with the S-, thus insuring that programmed changes in the relative frequency of S+ and S- presentations produced systematic changes in contact with these stimuli.

Initial training was composed of both multiple- and mixed-schedule periods: a MULT (MULT VI 40-s EXT/ MIX VI 40-s EXT) schedule. In the mixed schedule, the VI 40-s and EXT components were both signaled by the same stimulus, a continuously illuminated houselight. The superordinate multiple-schedule components alternated randomly without replacement every 10 min in the 60-min training sessions. This training was suggested by Branch (1973), because the common technique of introducing the mixed stimulus at the same time as the observing response, and after multiple-schedule training, may disrupt food-key performance in the presence of the mixed stimulus. Training continued until a clear discrimination developed between the three stimulus conditions, as determined by visual inspection of cumulative records.

Observing Response Training

Following the initial training sessions, the left (observing) key was introduced. Thereaf-

ter, in the absence of observing responses, the mixed stimulus was in place continuously. When the observing requirement was satisfied, the mixed stimulus was replaced for 3 s with either the S+ or S−, depending on the schedule (VI or EXT, respectively) currently in effect on the food key. If components changed from EXT to VI during the 3-s stimulus presentation, this was accompanied by a change from S− to S+. Because VI components terminated with a 3-s food delivery during training sessions, the schedule-correlated stimulus never changed from S+ to S− during a single presentation. A change-over delay (COD) that prevented the delivery of food for 1.5 s after an observing key peck was in place throughout training and all experimental conditions.

Initially the observing-key schedule requirement was fixed ratio 1 (FR 1). That is, every peck on the observing key changed the houselight from constantly on (mixed-schedule stimulus) to either S+ or S−. To facilitate acquisition of observing, the first five schedule-correlated stimuli presented were always S+ (observing during the EXT component had no programmed consequence). After several sessions this restriction was lifted, and the observing schedule was leaned to VI 10-s across several sessions. Due to low observing rates, Pigeon 96 was exposed to an additional condition in which schedule-correlated stimuli were produced only when observing interresponse times were 5 s or less. After this condition, the interresponse time requirement was lifted. For all pigeons, when observing rates were moderate and stable, the observing schedule was changed to a VI 20-s schedule and the experiment proper began.

A series of conditions was initially undertaken in which increasingly dense VT schedules of stimulus presentation were superimposed on the VI 20-s observing-key schedule (modeled after the procedure used by Rachlin & Baum, 1972, Experiment III-B). These conditions did not produce systematic effects and are therefore not reported here.

Procedure

Throughout the remainder of the experiment, food presentations were arranged according to a mixed/multiple schedule with VI 40-s and EXT components. Unlike the training sessions, component durations were determined by two identical 11-element rectangular distributions averaging 60 s (with components ranging from 10 s to 110 s) that were independent of all other experimental events. Thus, the delivery of food on the VI schedule no longer signaled the start of the EXT component. If the component changed during the 3-s interval in which the S+ or S− was presented, then the houselight stimulus was immediately changed to reflect this. Sessions ended after 40 food presentations or 75 min, whichever came first.

As shown in Table 1, the experiment was organized into three phases, each of which consisted of a similar block of conditions. Across phases the proportion of session time spent in VI was manipulated. This was accomplished by changing the values in the distribution comprising the durations of EXT components. Pigeons spent approximately 50%, 25%, and 75% of the session in the VI component during Phase 1, Phase 2, and Phase 3, respectively.

Throughout all phases, the programmed rate of schedule-correlated stimulus presentations was held constant at four per min while the dependency between observing responding and such stimulus presentations was manipulated within phase. Each phase began with a baseline condition in which schedule-correlated stimuli were produced according to a VI 15-s schedule, for an average of four response-dependent stimulus presentations per min, and no response-independent stimulus presentations (4, 0). After responding had stabilized in the baseline condition, the average number of response-dependent stimulus presentations was decreased and the average number of response-independent stimulus presentations was increased. For example, following the baseline condition in Phase 1, response-dependent stimulus presentations were decreased by one per min while response-independent presentations were increased by one (conjoint VI 20 s VT 60 s; 3, 1). As shown in Table, 1, this was done gradually in Phase 1 and more abruptly in Phases 2 and 3. All phases included a condition in which all stimulus presentations occurred independent of responding (VT 15 s; 0, 4) and this was followed by a replication of the VI 15-s baseline (4, 0).

Conditions were terminated after a minimum of 14 sessions had been conducted and a

Table 1

Order of conditions within phases and number of sessions per condition. Conditions are described by the schedule(s) operating on the observing key.

	Pigeon					
	457	250	1774	96	289	1770
Phase 1 (50% VI)						
VI 15 s	42	36	16	72	24	49
VI 20 s + VT 60 s	14	22	20	28	18	21
VI 30 s + VT 30 s	14	19	58	21	35	57
VI 60 s + VT 20 s	14	23	19	28	19	34
VT 15 s	17	16	41	15	22	18
VI 15 s	25	24	24	25	32	57
Phase 2 (25% VI)						
VI 15 s	25	14	15	22	14	16
VI 30 s + VT 30 s	38	17	14	15	14	36
VT 15 s	18	37	16	17	17	21
VI 15 s	29	40	18	15	27	26
Phase 3 (75% VI)						
VI 15 s	41	28	32	25	24	35
VI 30 s + VT 30 s	-	-	22	19	27	28
VT 15 s	16	-	13	16	16	15
VI 15 s *	-	14	-	-	-	-
VI 15 s	16	25	30	35	20	20

Note: * 50% of session time spent in VI during this condition.

judgment of stability had been made. Stability was determined by visual inspection of session rates of observing for individual subjects. Stability criteria required that no trend appear in the last 5 sessions of a condition and that neither the highest or lowest session rates of observing responses were contained in the last 5 sessions of a condition.

When Phase 3 began, rates of observing decreased substantially for Pigeons 250 and 457. Guidelines were therefore established to determine the sequence of conditions in Phase 3, tailored to individual pigeons' performances. For Pigeon 250, because the mean rate of observing across the last five sessions of the Phase 3 baseline condition was less than one per min, no conditions involving response-independent stimulus presentation were conducted. Instead, an A–B–A reversal was conducted in which the proportion of total session time spent in VI was changed from 75% to 50%, and then back to 75%. For Pigeon 457, mean rates of observing were somewhat higher than for Pigeon 250 but still less than one-third of the rate observed in the Phase 2 baseline-replication condition. Thus, an A–B–A reversal was conducted in which the schedule operating on the observing key was changed from VI 15 s to VT 15 s and then back to VI 15 s. The sequence of Phase 3

conditions for the other 4 pigeons was similar to the sequence of conditions conducted in Phase 2 (see Table 1).

RESULTS

Figure 1 shows the mean rates of observing responses for the last five sessions of each condition as a function of the programmed percent of response-dependent schedule-correlated stimulus presentations. Rate of observing was calculated by dividing the number of observing key pecks in the absence of a schedule-correlated stimulus by the number of minutes spent in session in the absence of a schedule-correlated stimulus. Within each phase, the rate of pecking the observing key tended to increase with increases in the programmed percent of response-dependent schedule-correlated stimulus presentations. This increasing trend in rate of observing is apparent in all phases across all subjects. Comparisons between conditions of maximal and minimal dependency show lower rates in the latter for 16 of 16 comparisons.

Comparisons between Phases 1 and 2 indicate that observing rates did not change substantially when the proportion of session time spent in VI was decreased from 50% to 25%, although rates were slightly higher under
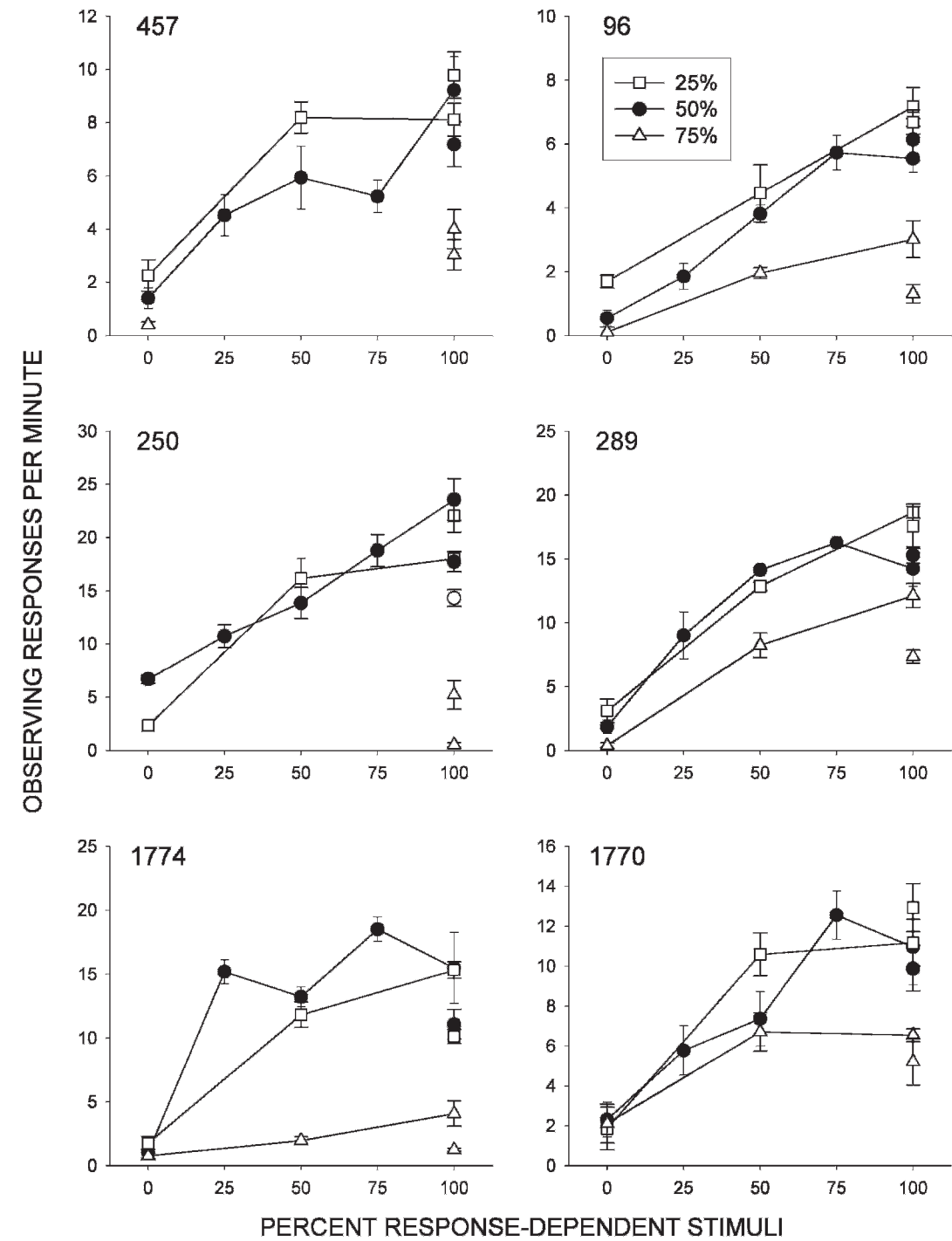
Fig. 1.   Rate of observing responses as a function of programmed percent of response-dependent schedule-correlated stimulus presentations. Symbols indicate proportion of total session time spent in VI. Error bars show standard deviations. Unconnected points are from replicated conditions. Open circle (Pigeon 250 only) indicates a replication of the 50% VI baseline condition between exposures to the 75% VI baseline. Note individually-scaled y-axes for each pigeon.
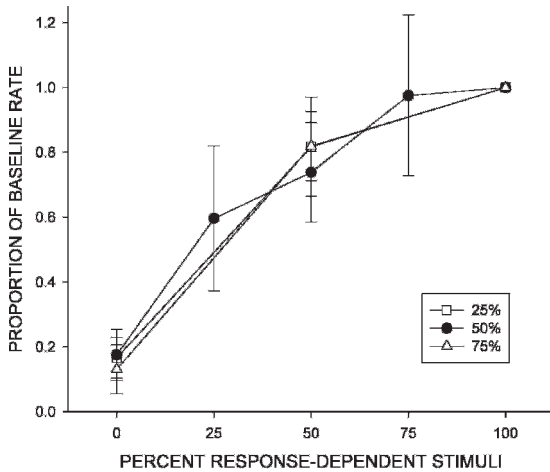
Fig. 2. Normalized group mean rate of observing responses as a function of programmed percent of response-dependent schedule-correlated stimulus presentations. Symbols indicate proportion of total session time spent in VI. Error bars show standard deviations.

Phase 2 conditions (25% VI) in 14 of 21 cases. Phase 3 conditions (75% VI) generated lower rates of observing than comparable conditions in Phases 1 and 2.

Figure 2 shows group mean rate of observing key pecks for all conditions, expressed as a proportion of the group mean observing rates obtained in the first baseline condition of each phase. This normalized analysis was conducted to assess the extent to which changes in the proportion of session time spent in VI (manipulated across phases) interacted with changes in the programmed percent of response-dependent schedule-correlated stimuli. The extensive overlap of the three functions on this figure indicates that these variables produced simple additive effects on observing. A similar analysis conducted on individual subjects' data revealed the same pattern for all subjects.

Figure 3 shows the mean discrimination index (DI) for food-key responding in the presence of the schedule-correlated stimuli for the last five sessions of each condition as a function of the programmed percent of response-dependent schedule-correlated stimuli. The DI was calculated using the rate of key pecking on the food key in the presence of S+, divided by this value plus the rate of key pecking in the presence of S−. This measure indicates strong control of food-key respond-ing by schedule-correlated stimuli for all pigeons across all conditions. All pigeons showed increases in the discrimination index as the percent of response-dependent stimulus presentations increased. Between-phase comparisons indicate that proportion of session time spent in VI did not systematically affect discriminability of the schedule-correlated stimuli, as indicated by the overlapping curves for 5 of 6 subjects. Table 2 shows mean rate of response on the food key for the last five sessions of each condition in the presence of S+, S−, and the mixed stimulus.

DISCUSSION

The results of the present experiment show that observing responses were controlled by the dependency between observing and the presentation of schedule-correlated stimuli. Specifically, decreases in the dependency ratio decreased rates of responding on the observing key. This result extends the findings of Lattal (1974) to behavior maintained by conditioned reinforcement and is consistent with the findings of Lieving et al. (2006).

Podlesnik and Shahan (2008) conducted two experiments that bear some similarity to ours in that they disrupted the dependency between responding and a primary reinforcer whereas we disrupted the dependency between responding and the presentation of schedule-correlated stimuli (conditioned reinforcers). In their first experiment, rats were exposed to multiple schedules in which one component was a VI schedule and another component was an identical VI schedule with superimposed VT food deliveries. Response rates were slightly higher in the component that included VT food deliveries and this finding is at odds with our pigeons' tendency to decrease observing response rates when conditioned reinforcers were increasingly de-livered response-independently. This discrep-ancy may have occurred because Podlesnik and Shahan did not hold constant the overall density of food presentations whereas we held constant the rate at which conditioned rein-forcers were presented. In a second experi-ment, Podlesnik and Shahan held food-pre-sentation rate constant across multiple-schedule components using a procedure sim-ilar to ours. This yielded findings similar to those of the present report: response rates
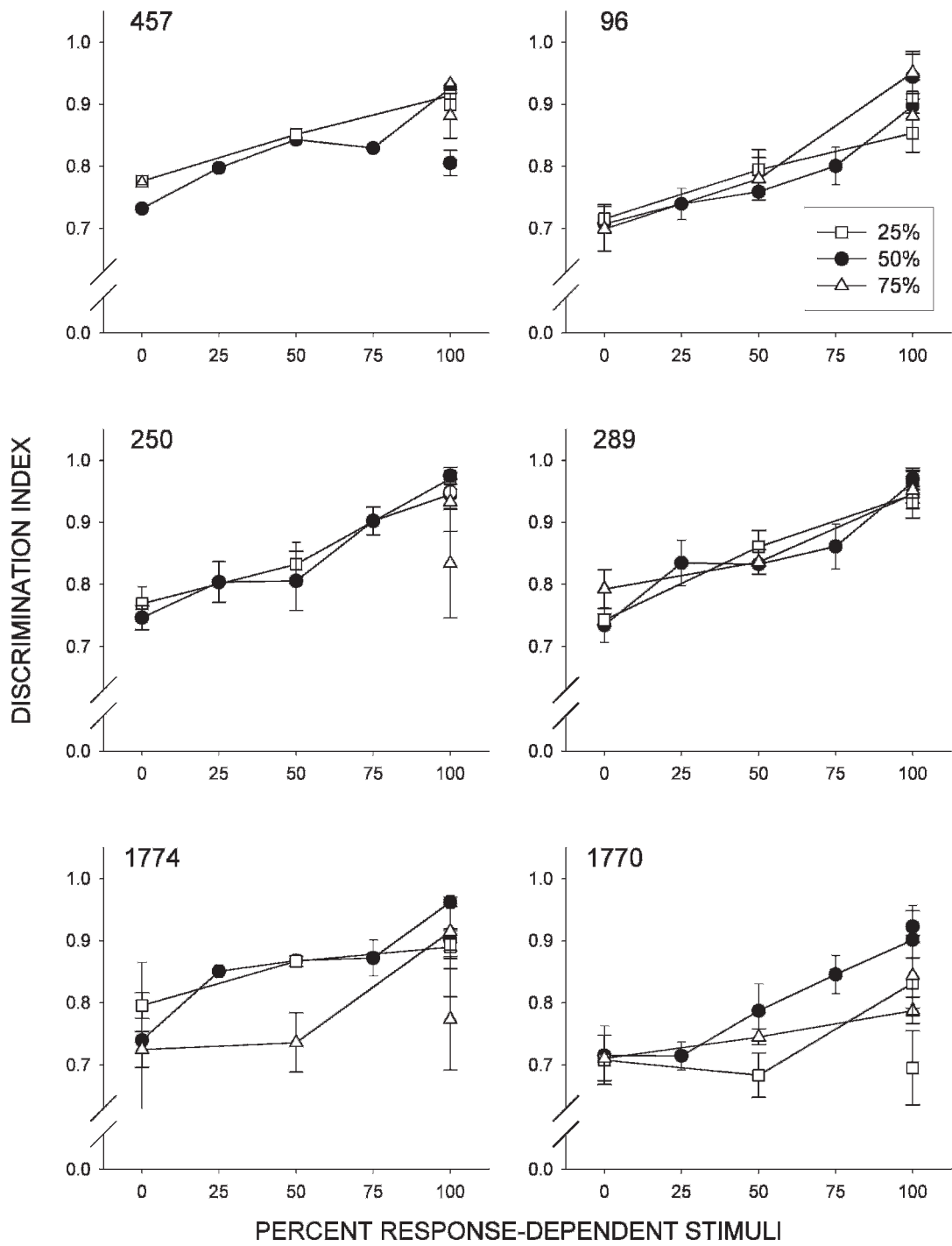
Fig. 3. Discrimination index of food-key responding in the presence of schedule-correlated stimuli as a function of programmed percent of response-dependent schedule-correlated stimulus presentations. Symbols indicate proportion of total session time spent in VI. Unconnected points are from replicated conditions. Error bars show standard deviations. Open circle (Pigeon 250 only) indicates a replication of the 50% VI baseline condition between exposures to the 75% VI baseline.

Table 2

Rate of responding (resp/min) on the food key in the presence of S+, S−, and mixed stimuli during the last five sessions of each condition.

		Pigeon					
		457	250	1774	96	289	1770
Phase 1 (50% VI)							
VI 15 s	S+	60.4	74.3	154.7	58.0	58.4	44.1
	S−	4.9	4.4	6.1	6.7	2.2	4.9
	Mix	37.4	55.7	122.3	42.0	39.5	59.1
VI 20 s + VT 60 s	S+	62.1	78.2	158.9	54.3	51.9	59.8
	S−	12.9	8.5	23.3	13.7	8.5	10.9
	Mix	45.5	59.0	123.9	38.7	36.6	66.4
VI 30 s + VT 30 s	S+	56.0	81.3	121.3	50.2	48.6	32.9
	S−	10.4	19.8	18.6	16.0	9.8	9.0
	Mix	39.0	63.4	115.0	32.4	34.0	57.8
VI 60 s + VT 20 s	S+	57.6	77.1	121.1	50.4	41.9	42.3
	S−	14.7	18.8	21.3	17.8	8.4	16.9
	Mix	39.8	58.6	113.1	37.3	32.8	58.2
VT 15 s	S+	58.7	76.8	102.9	47.0	42.1	44.5
	S−	21.6	26.1	34.3	19.5	15.2	18.0
	Mix	43.9	59.0	95.5	34.1	35.3	70.1
VI 15 s	S+	56.5	79.0	125.5	55.0	51.1	33.4
	S−	13.7	2.0	13.8	3.4	1.6	2.8
	Mix	36.5	51.7	112.3	33.1	32.5	66.3
Phase 2 (25% VI)							
VI 15 s	S+	61.1	70.0	81.0	57.9	51.4	26.4
	S−	5.7	2.1	8.9	10.0	3.0	5.3
	Mix	23.5	47.8	87.5	34.0	28.8	53.2
VI 30 s + VT 30 s	S+	58.6	70.1	100.6	51.7	44.7	32.8
	S−	10.2	14.2	15.4	13.3	7.2	15.2
	Mix	24.2	50.5	94.0	29.7	27.0	57.0
VT 15 s	S+	46.8	72.4	106.5	55.4	40.4	54.7
	S−	13.6	21.6	27.5	22.0	14.0	22.6
	Mix	28.3	49.6	103.5	31.4	33.5	62.3
VI 15 s	S+	44.2	71.0	108.9	48.6	54.6	29.7
	S−	5.0	1.9	13.0	4.9	4.0	12.8
	Mix	24.9	51.2	109.2	32.1	29.0	61.3
Phase 3 (75% VI)							
VI 15 s	S+	57.4	73.0	140.7	59.2	57.1	46.8
	S−	4.1	15.0	13.2	3.1	3.3	12.6
	Mix	42.5	65.1	104.9	35.2	41.2	83.6
VI 30 s + VT 30 s	S+	-	-	102.6	50.3	51.5	52.9
	S−	-	-	37.5	14.3	10.2	18.1
	Mix	-	-	87.5	32.3	41.0	81.6
VT 15 s	S+	49.6	-	99.0	43.5	45.9	55.0
	S−	14.4	-	37.9	18.7	12.1	22.5
	Mix	48.3	-	83.9	33.9	41.8	85.8
VI 15 s *	S+	-	76.1	-	-	-	-
	S−	-	2.9	-	-	-	-
	Mix	-	57.8	-	-	-	-
VI 15 s	S+	65.4	81.0	154.3	75.1	51.4	40.2
	S−	9.0	6.1	46.0	10.5	2.7	7.4
	Mix	50.3	64.4	96.9	38.1	44.1	72.5

Note. * 50% of session time spent in VI during this condition.

were lower in components in which some food deliveries were independent of responding. This similarity suggests that degrading the response–reinforcer contingency produces similar results regardless of whether the reinforcer is food or brief access to schedule-correlated stimuli.

It should be noted that our technique for manipulating the dependency between observing responses and the delivery of schedule-

correlated stimuli confounded reductions in the rate of response-dependent conditioned reinforcement with concomitant increases in the rate of response-independent stimulus delivery (Burgess & Wearden, 1986). However, the endpoint conditions, in which only response-dependent or response-independent presentations of schedule-correlated stimuli were available, clearly illustrate the importance of dependency in conditioned reinforcement.

The results of several studies indicated that conditioned stimuli do not necessarily function like unconditioned reinforcers such as food (e.g., Davison & Baum, 2006; Schuster, 1969), but the procedures used in such studies did not feature a response maintained exclusively by the presentation of schedule-correlated stimuli as in the observing procedure. Taken together with the present results, this suggests that the extent to which conditioned stimuli serve a reinforcing function may vary depending on the particular relations arranged between responding and the presentation of conditioned stimuli.

Across-phase changes in the proportion of session time spent in VI components of a mixed schedule of food delivery produced orderly changes in rate of observing key pecks. Pigeons observed at their lowest rates in the 75% VI phase. Observing rates in the 50% VI and 25% VI phases were comparable and higher than in the 75% VI phase. In the presence of the mixed stimulus, observing responses were most likely during EXT components for all pigeons throughout the experiment. These effects are similar to those obtained in prior research (e.g., McMillan, 1974). Wilton and Clements (1971) described a theoretical function relating the reinforcing value of S$^+$ presentations to the probability of their presentation. According to this function, the 50% and 25% VI phases should produce identical rates of response on the observing key, but the 75% VI phase should produce considerably lower rates of observing behavior. The present data are consistent with this prediction: Rate of observing behavior was similar across the 50% and 25% VI phases, but dropped considerably during the 75% VI phase.

The interplay between observing and food-key responding suggests that the schedule-correlated stimuli serve multiple functions, discriminative as well as reinforcing. Indeed,

the observing procedure, as developed by Wyckoff (1952, 1969), was designed to investigate discrimination learning. In bringing observing under experimental control, Wyckoff's procedure allowed for precise measurement of responses deemed analogous to natural orienting responses such as head or whole body movements toward a stimulus. Wyckoff reasoned that such orienting responses were a critical part of discrimination learning, and that it was probable that any unobservable ''attending responses'' were likely to be controlled by the same mechanisms that controlled the observing response. Thus, questions concerning the discriminative function of stimuli were of central importance.

The present study expanded the analysis of observing to response-independent presentation of food-correlated stimuli, and in so doing, returned to Wyckoff's original emphasis on discriminative processes. The discrimination index for food-key responding in the presence of schedule-correlated stimuli decreased as the dependency between observing key pecks and stimulus presentations decreased. This was due mainly to increases in food-key response rates during S− presentations. The increased rate of food-key responding during S− also suggests that the pigeons did not move away from the intelligence panel during S− presentations, and this was verified during informal observations of the experimental sessions. Delivering the schedule-correlated stimuli via the houselight instead of on the key probably prevented the development of withdrawal responses that would have interfered with key pecking during S− presentations. Thus, the decrease in stimulus control shown in Figure 3 is a direct function of changes in the dependency, as evidenced by the graded function relating these variables.

That the relationship between discriminative control and observing has not been demonstrated previously is probably due to the decades-old controversy surrounding the maintenance of observing responses in Wyckoff's procedure. Although Wyckoff's initial interest was in discriminative processes, the procedure came to be used primarily to investigate the consequences maintaining observing. Indeed, because of its ability to disentangle responses maintained by food-correlated stimuli from those maintained by food, the observing procedure has played an

important role in the analysis of conditioned reinforcement (see Dinsmoor, 1983; Fantino, 1977, for reviews). The present study shows that the observing procedure has not yet been fully explored as a method for studying antecedent–behavior relations.

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